Mars Sample Return Architecture

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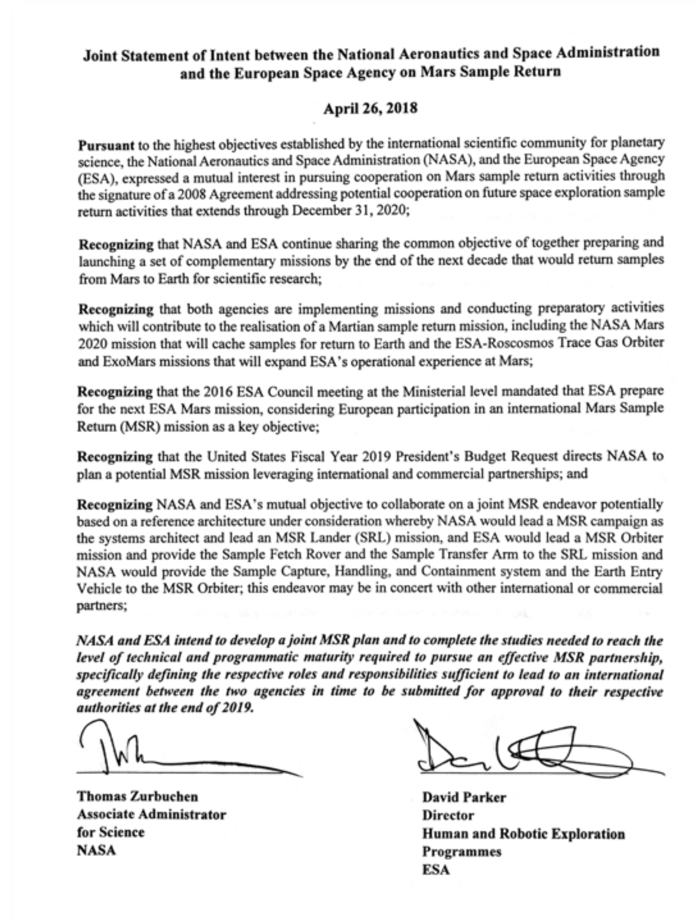
NASA-ESA Joint Statement of Intent

- *On April 26, 2018, in conjunction with the 2nd International MSR Conference in Berlin, GER, NASA and ESA signed a Joint Statement of Intent on Mars Sample Return*
- NASA:
  - Lead MSR Campaign system architecture
  - Lead Sample Retrieval Lander mission
  - Provide Capture/Containment and Return System (CCRS) to ERO
- ESA:
  - Lead Earth Return Orbiter mission
  - Provide Sample Fetch Rover and Sample Transfer Arm to SRL
- *Joint plan to be developed for NASA/ESA approval by the end of CY 2019*



Joint Statement of Intent between the National Aeronautics and Space Administration and the European Space Agency on Mars Sample Return

April 26, 2018

Pursuant to the highest objectives established by the international scientific community for planetary science, the National Aeronautics and Space Administration (NASA), and the European Space Agency (ESA), expressed a mutual interest in pursuing cooperation on Mars sample return activities through the signature of a 2008 Agreement addressing potential cooperation on future space exploration sample return activities that extends through December 31, 2020;

Recognizing that NASA and ESA continue sharing the common objective of together preparing and launching a set of complementary missions by the end of the next decade that would return samples from Mars to Earth for scientific research;

Recognizing that both agencies are implementing missions and conducting preparatory activities which will contribute to the realisation of a Martian sample return mission, including the NASA Mars 2020 mission that will cache samples for return to Earth and the ESA-Roscosmos Trace Gas Orbiter and ExoMars missions that will expand ESA's operational experience at Mars;

Recognizing that the 2016 ESA Council meeting at the Ministerial level mandated that ESA prepare for the next ESA Mars mission, considering European participation in an international Mars Sample Return (MSR) mission as a key objective;

Recognizing that the United States Fiscal Year 2019 President's Budget Request directs NASA to plan a potential MSR mission leveraging international and commercial partnerships; and

Recognizing NASA and ESA's mutual objective to collaborate on a joint MSR endeavor potentially based on a reference architecture under consideration whereby NASA would lead a MSR campaign as the systems architect and lead an MSR Lander (SRL) mission, and ESA would lead a MSR Orbiter mission and provide the Sample Fetch Rover and the Sample Transfer Arm to the SRL mission and NASA would provide the Sample Capture, Handling, and Containment system and the Earth Entry Vehicle to the MSR Orbiter; this endeavor may be in concert with other international or commercial partners;

NASA and ESA intend to develop a joint MSR plan and to complete the studies needed to reach the level of technical and programmatic maturity required to pursue an effective MSR partnership, specifically defining the respective roles and responsibilities sufficient to lead to an international agreement between the two agencies in time to be submitted for approval to their respective authorities at the end of 2019.

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Associate Administrator
for Science
NASA

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Human and Robotic Exploration
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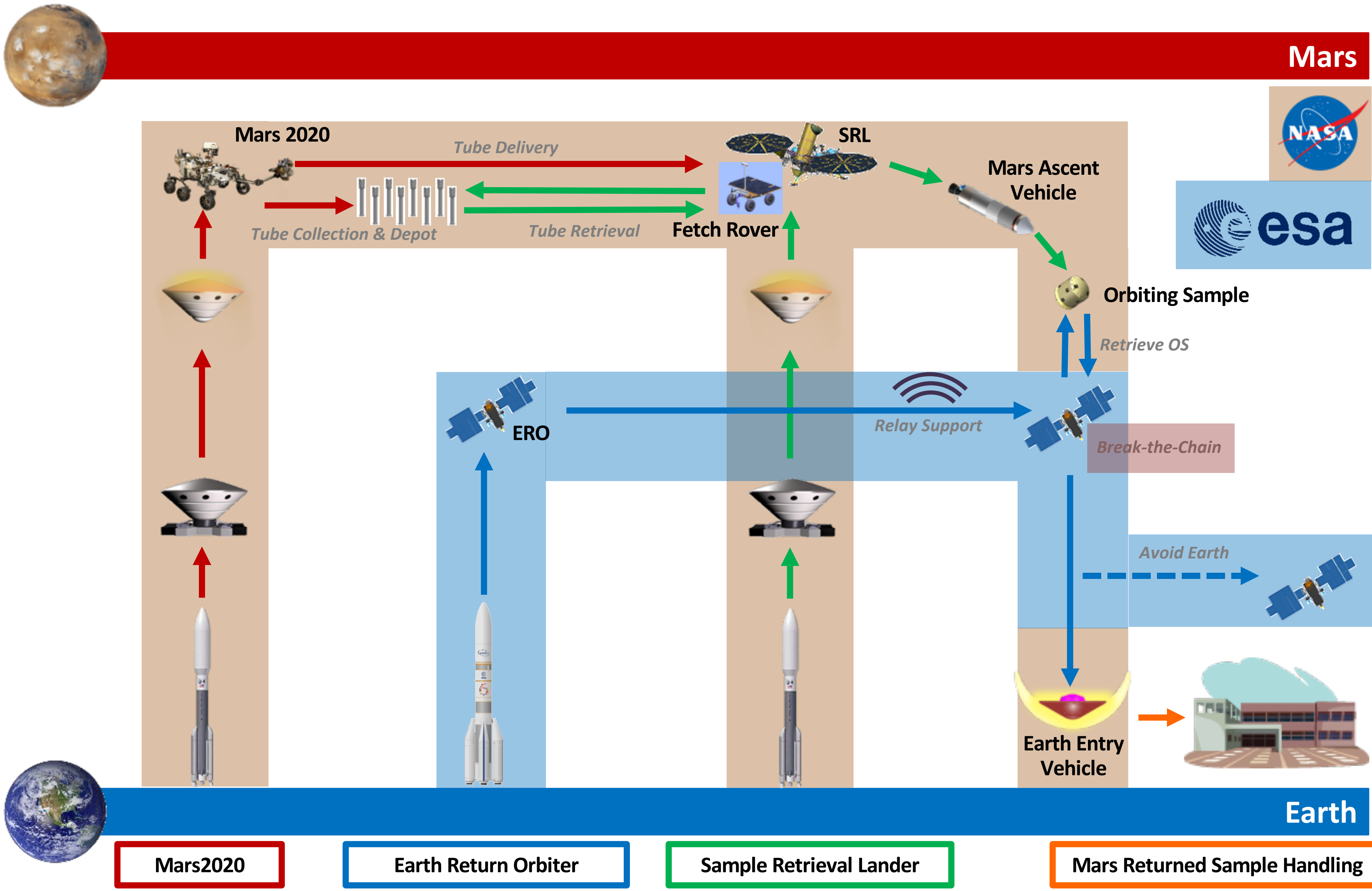
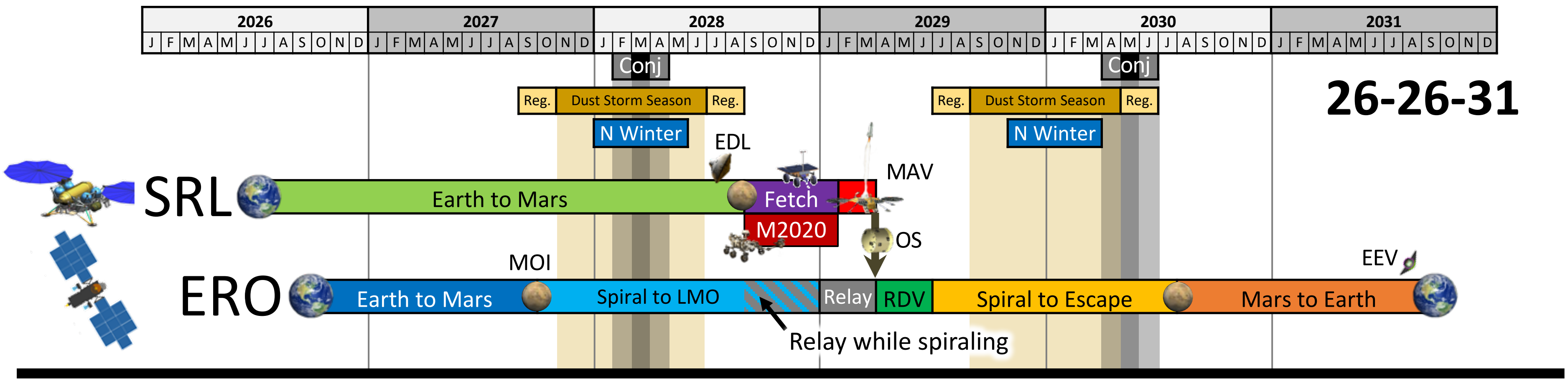
ESA

Notional Mars Sample Return Campaign Strategy



Notional Mission Timeline



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SRL Launches in 2026

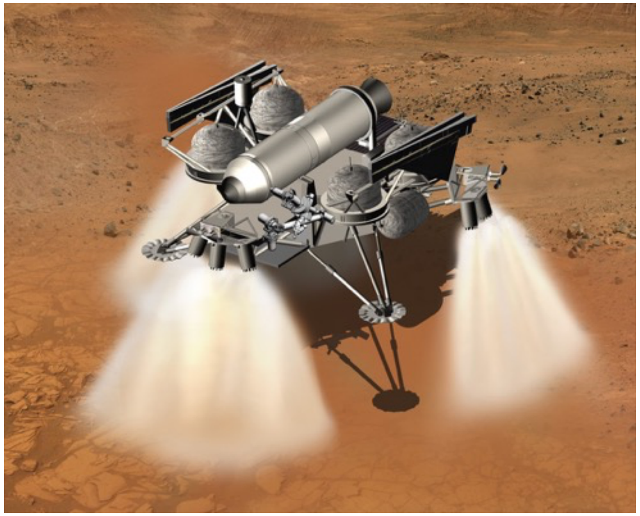
ERO launches in 2026

Samples are returned in 2031

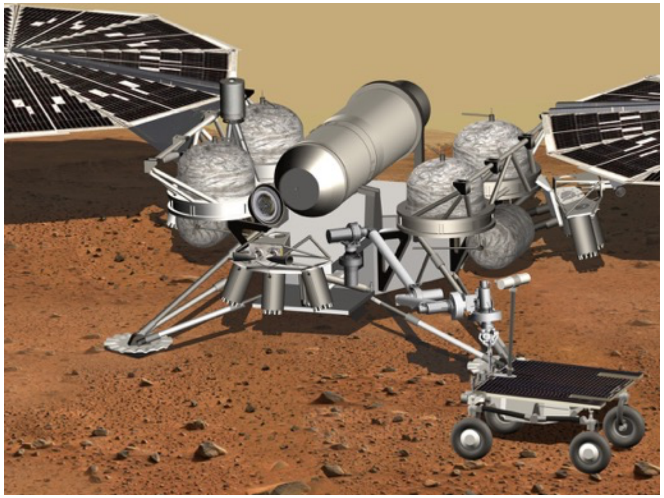
- SRL avoids northern winter, global dust storm season, and conjunctions
- SRL EDL occurs in a favorable season, maximizing landed mass
- SRL compatible with sample delivery by SFR and/or M2020
- ERO can provide all relay services needed for MSR (SRL, SFR, M2020, MAV)
- SRL, ERO, and M2020 timelines are coupled and highly interactive

Sample Retrieval Lander Concept Overview

- Key Functional Capabilities
  - Land near Jezero Crater (final landing target dependent on M2020 and cache depot locations at time of arrival)
  - Deploy ESA-provided Sample Fetch Rover
  - Receive sample tubes delivered by both M2020 and SFR; utilize ESA-provided Sample Transfer Arm to load sample tubes into Orbiting Sample container on MAV
  - Launch MAV and release OS into stable low-Mars orbit (>300 km altitude)
- Design Status
  - M2020-heritage cruise stage
  - Propulsive Platform Lander (Viking/Phoenix/InSight-heritage)
    - M2020-heritage Terrain-Relative Navigation
  - Solar-powered (no RTG/RHU)
  - Atlas V-class launch vehicle

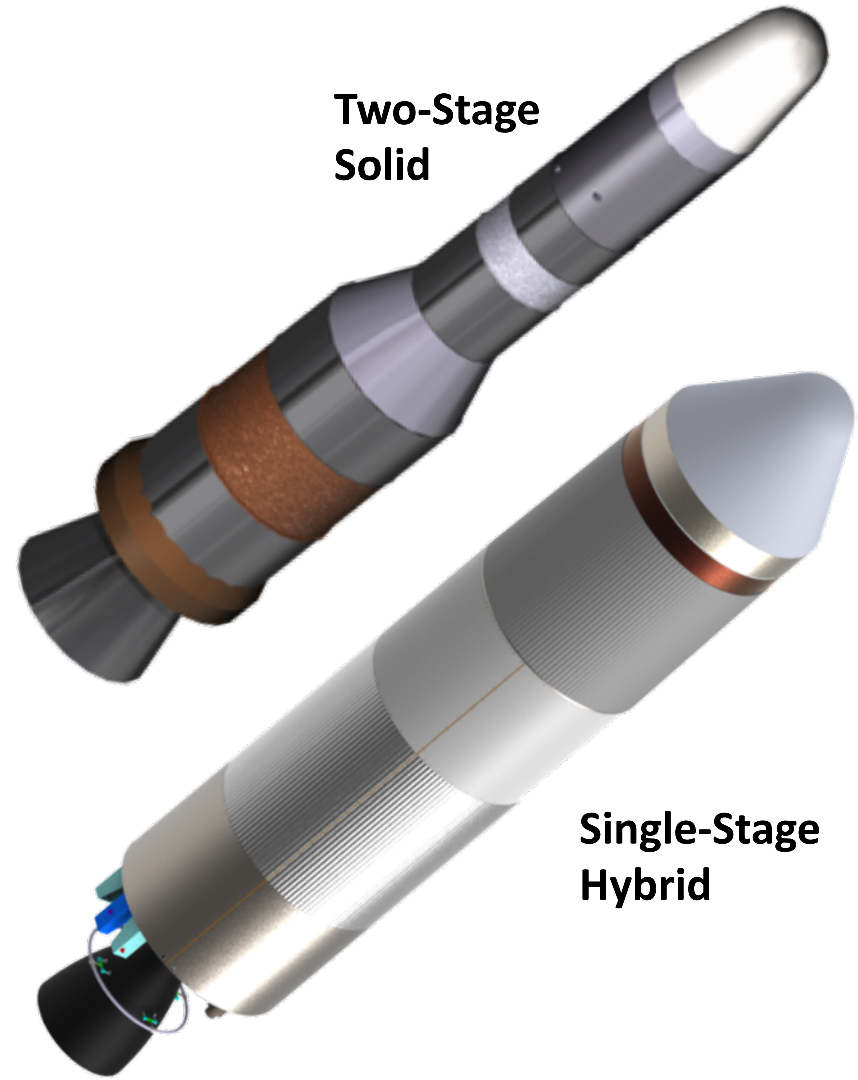


Propulsive Platform Lander concept



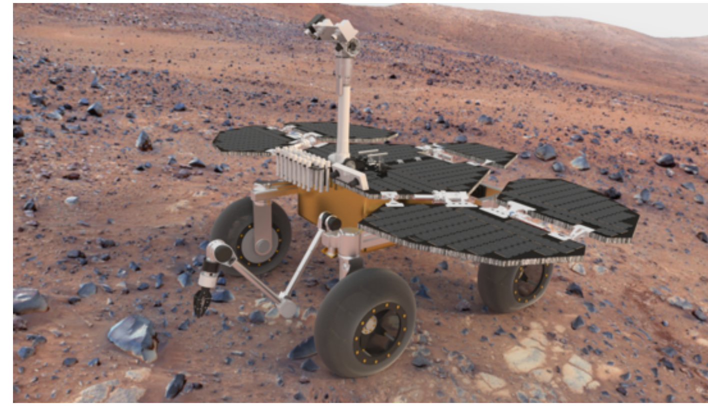
MAV Concept Overview

- Key Functional Capabilities
  - Receive 20-30 sample tubes into OS
  - Launch OS into >300 km orbit, 18-25 deg inclination with dispersion of <1 deg
- Technology and Design Status
  - Evaluating two MAV technology options:
    - Single-State Hybrid Propulsion
    - Two-Stage Solid Propulsion
  - Hybrid:
    - Focus on demonstrating reliable ignition, stable combustion, and restart capability
  - Solid:
    - Higher heritage; focus on demonstrating compatibility with Mars surface thermal environment
  - Both vehicle designs are maturing to meet performance, mass and volume constraints
    - Final down-select planned by Nov 2019



Fetch Rover Concept (ESA provided)

- Key Functional Capabilities
  - Acquire M2020 cached sample tubes
  - Surface mission duration: 150 sols max
  - Average traverse distance required: 150-250 m/sol
- Design Status
  - Initial accommodation and egress designs defined (Phase A completed)
  - Rover Mass: ~140 kg
  - Navigation: Advanced image processing to support highly autonomous driving
  - Telecom: UHF relay to orbiters
- M2020 Delivery
  - Lander designed for M2020 tube delivery providing a robust mission approach of either or both delivering sample tubes

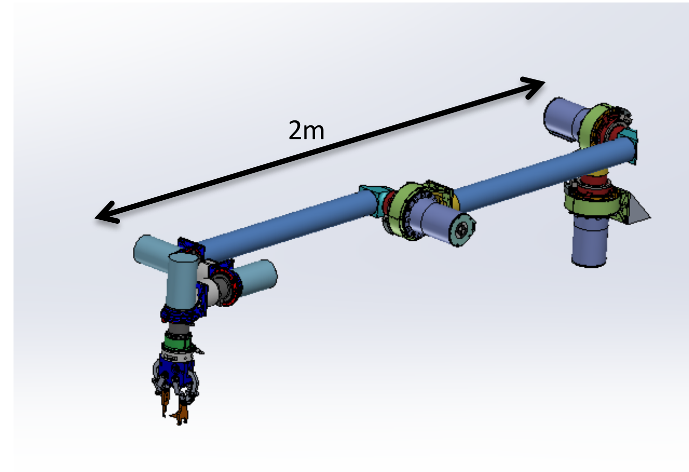


Concept of ESA Sample Fetch Rover

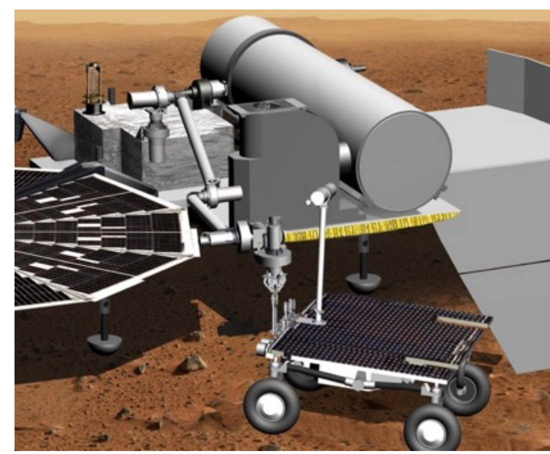
Scale is roughly 2/3 of MER, but with much larger wheels!

Transfer Arm Concept (ESA provided)

- Key Functional Capabilities
  - Transfer the sample tubes from the Sample Fetch Rover (and/or Mars 2020) to the sample container on the ascent vehicle
  - Vision-based autonomy required due to timeline constraints.
- Design Status
  - Parallel Phase A activities just started
  - Breadboarding activity planned between 2019 and 2021.
- ESA Technology heritage
  - DELIAN (Lightweight arm for Mars)
  - European Robotic Arm (for ISS)
  - DEXARM (for ISS)

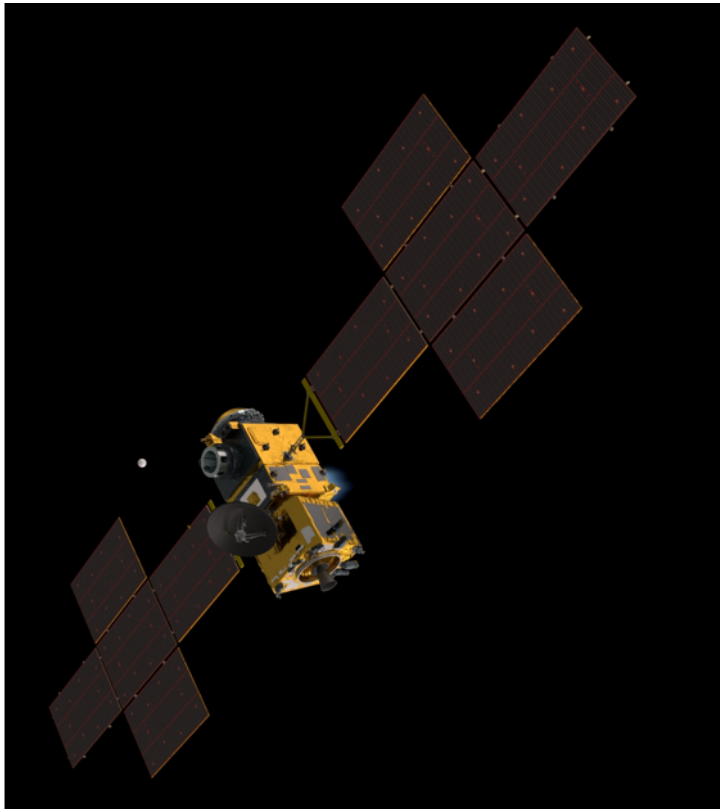


Sample Transfer Arm concept


STA on Lander

Earth Return Orbiter Concept Overview

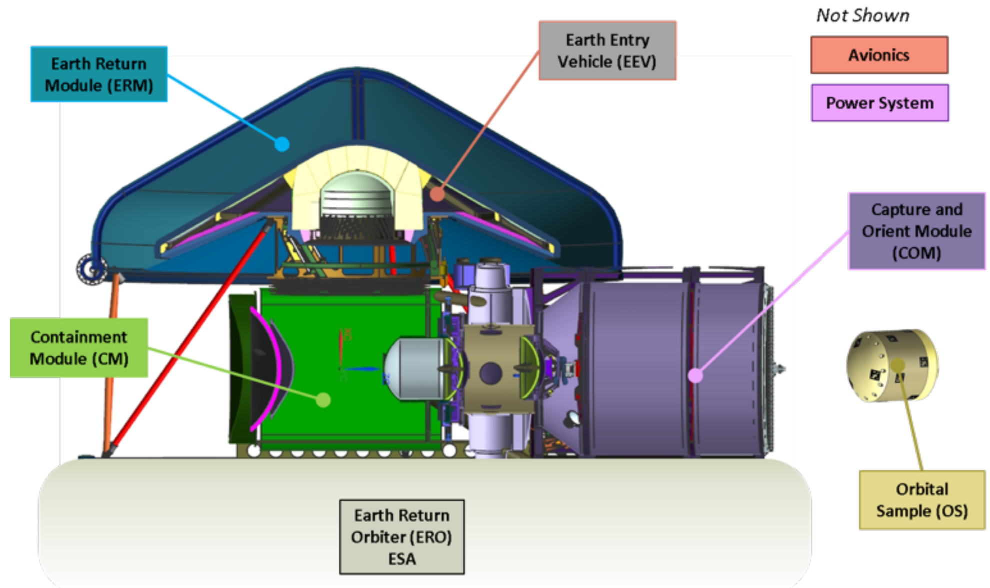
- Key Functional Requirements
  - Provide telecom relay services to M2020, SRL, SFR, and MAV throughout SRL surface mission
  - Accommodate the NASA-supplied Capture/Containment and Return System Payload
  - Locate, rendezvous with, capture, and contain the OS, and transfer to the EEV
  - Return to Earth and release EEV on trajectory to selected Earth landing site
  - Deflect ERO to avoid Earth impact
- Design Status
  - Hybrid propulsion (40kW Electric + Chemical) architecture => heritage from Bepi Colombo mission
  - Feasibility demonstrated (Phase A completed). Systems Requirements Review planned for Q1 2020.
  - Cost, risks identified and development plan in place for launch in 2026.

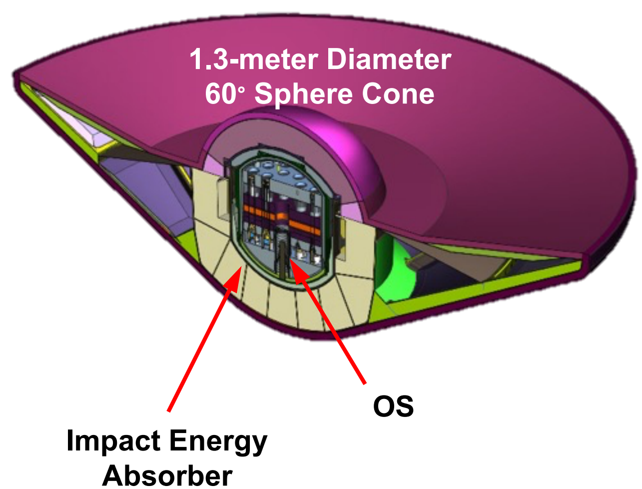


Concept of ESA's Earth Return Orbiter

Capture/Containment and Return System Concept

- Key Functional Requirements
  - Capture the OS on-orbit
  - Orient the OS
  - Transfer OS to EEV
  - Release EEV to target Earth landing site
  - Satisfy back-PP requirements
- Technology and Design Status
  - Break-the-Chain/Containment Assurance
    - High/medium-temperature brazing options for OS containment
    - Potential use of chemical/plasma sterilization methods to mitigate potential Mars dust on OS exterior
  - Robust, aerodynamically stable EEV entry system
    - Passive, ballistic entry; no parachute or propulsion





Mars Returned Sample Handling (MRSH)

Notional 3-Component Architecture

Landing of sample in entry capsule at UTTR (tbd)

Ground Recovery Operations (GRO)

- Safing of entry capsule
- Quarantine capsule and protect samples
- Transfer capsule to SRF
- Site remediation

GRO

Sample Receiving Facility (SRF)

- Quarantine & isolate from terrestrial contamination
- Sample Characterization
- Perform life and biohazard testing
- Acquire safety certification

One Example

- Assumes one facility in US.
- International
  - Governance
  - Access
  - Contributions

SRF Location TBD

Samples transferred only if release criteria are met

SCF Location TBD

Distributed Science

(Competitive Investigators)

- Assumes at least one facility in US.
- Potential benefit if another outside US.
  - Sample safety
  - International buy-in
- If only one in US, international allocation process.

Sample Curation Facility (SCF)

- Protect and preserve
- Distribute and control

Key Technical Trades

Trade	Options
SRL EDL	• Increased EDL divert could reduce landing dispersion below M2020-heritage ~4 km, reducing SFR drive requirement
OS Size	• Currently assessing 20-30 returned tubes; dependent on MAV performance results
MAV	• Single-stage hybrid vs. Two-stage solid options
SFR	• Mobility and autonomy requirements dependent on SRL landing accuracy • Egress approach from SRL
ERO	• SEP implementation and SA power vs mission timeline
EEV	• TPS (HEEET vs. PICA) • Release strategy and final targeting accuracy

Near-Term Plans

- Architecture Closure Review in Oct 2019
  - Follow-up to Sep 2018 MSR Campaign Mid-Term Architecture Peer Review
  - Goal is to close remaining MSR architecture trades and establish reference campaign architecture
- SFR Phase B1 start in June 2019
  - Phase B2/C/D/E Request for Quotation in Q1 2020, Phase B2 start in mid 2020.
- ERO Phase B2/C/D/E Initiation to Tender release in Summer 2019
  - Intended Phase B2 start in Q1 2020
- Space19+ in end Nov 2019
  - decision on ESA MSR funding
- ESA-NASA MSR MOU soon after Space19+

Summary

- The Mars 2020 rover mission is gathering samples that could be returned by this notional architecture
- NASA and ESA have committed to jointly studying the retrieval missions of an MSR campaign for launch in the 2020’s
- Working together over the past year, the two agencies have made significant progress in defining the key MSR campaign elements and their interfaces
- Scenarios for SRL/ERO launch as early as 2026 are being studied, leading to return of samples to Earth by 2031
- The coming year will be key in terms of establishing NASA and ESA agency commitments to proceed with the MSR campaign.